FINAL REPORT
NASA Grant: NAG 5-2028

Hard Gamma Ray Emission from the Starburst Galaxy NGC 253

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We have completed the study to search for hard gamma ray emission from the starburst galaxy NGC 253. Since supernovae are thought to provide the hard gamma ray emission from the Milky Way, starburst galaxies, with their extraordinarily high supernova rates, are prime targets to search for hard gamma ray emission.

We conducted a careful search for hard gamma ray emission from NGC 253 using the archival data from the EGRET experiment aboard the CGRO. Because this starburst galaxy happens to lie near the South Galactic Pole, the Galactic gamma ray background is minimal. We found no significant hard gamma ray signal toward NGC 253, although a marginal signal of about 1.5 sigma was found. Because of the low Galactic background, we obtained a very sensitive upper limit to the emission of > 100 MeV gamma-rays of 8×10^{-8} photons cm^{-2} s^{-1}.

Since we expected to detect hard gamma ray emission, we investigated the theory of gamma ray production in a dense molecular medium. We used a leaky-box model to simulate diffusive transport in a starburst region. Since starburst galaxies have high infrared radiation fields, we included the effects of self-Compton scattering, which are usually ignored.

By modelling the expected gamma-ray and synchrotron spectra from NGC 253, we find that roughly 5 - 15 % of the energy from supernovae is transferred to cosmic rays in the starburst. This result is consistent with supernova acceleration models, and is somewhat larger than the value derived for the Galaxy (3 - 10%). Our calculations match the EGRET and radio data very well with a supernova rate of 0.08 yr^{-1}, a magnetic field $B \gtrsim 5 \times 10^{-5}$ G, a density $n \lesssim 100$ cm^{-3}, a photon density $U_{ph} \sim 200$ eV cm^{-3}, and an escape time scale $\tau_0 \lesssim 10$ Myr. The models also suggest that NGC 253 should be detectable with only a factor of 2 - 3 improvement in sensitivity. Our results are consistent with the standard picture of gamma-ray acceleration by supernovae.

The results are published in the *Astrophysical Journal* in the paper "Diffuse Gamma Ray Emission from the Starburst Galaxy NGC 253", Paglione, T.A.D., Marscher, A.M., Jackson, J.M., and Bertsch, D.A., 1996, *Astrophysical Journal*, **460**, 295. I enclose a reprint of the paper.